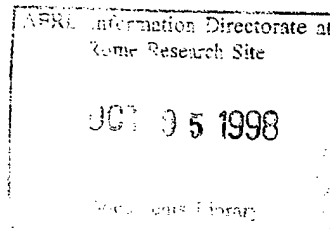


AFRL-IF-RS-TR-1998-158
Final Technical Report
July 1998



GCCS SPATIAL DATA BASE MODULE EXTENSIONS

Sterling Software

Paul Bell, David Kolassa, Michael McQuinn, Sandra Stoltz, William Reid, Jason Hamshar, and Christopher Williams

APPROVED FOR PUBLIC RELEASE; DISTRIBUTION UNLIMITED.

**AIR FORCE RESEARCH LABORATORY
INFORMATION DIRECTORATE
ROME RESEARCH SITE
ROME, NEW YORK**

20000516 021

DTIC QUALITY INSPECTED 1

This report has been reviewed by the Air Force Research Laboratory, Information Directorate, Public Affairs Office (IFOIPA) and is releasable to the National Technical Information Service (NTIS). At NTIS it will be releasable to the general public, including foreign nations.

AFRL-IF-RS-TR-1998-158 has been reviewed and is approved for publication.



APPROVED:

DOUGLAS M. BERIDON, 1Lt, USAF
Project Engineer



FOR THE DIRECTOR:

JOSEPH CAMERA, Deputy Chief
Information and Intelligence Exploitation Division
Information Directorate

If your address has changed or if you wish to be removed from the Air Force Research Laboratory Rome Research Site mailing list, or if the addressee is no longer employed by your organization, please notify AFRL/IFEB, 32 Brooks Road, Rome, NY 13441-4114. This will assist us in maintaining a current mailing list.

Do not return copies of this report unless contractual obligations or notices on a specific document require that it be returned.

REPORT DOCUMENTATION PAGE			Form Approved OMB No. 0704-0188	
<small>Public reporting burden for this collection of information is estimated to average 1 hour per response, including the time for reviewing instructions, searching existing data sources, gathering and maintaining the data needed, and completing and reviewing the collection of information. Send comments regarding this burden estimate or any other aspect of this collection of information, including suggestions for reducing this burden, to Washington Headquarters Services, Directorate for Information Operations and Reports, 1215 Jefferson Davis Highway, Suite 1204, Arlington, VA 22202-4302, and to the Office of Management and Budget, Paperwork Reduction Project (0704-0188), Washington, DC 20503.</small>				
1. AGENCY USE ONLY (Leave blank)	2. REPORT DATE July 1998	3. REPORT TYPE AND DATES COVERED Final Jun 96 - Jul 97		
4. TITLE AND SUBTITLE GCCS SPATIAL DATA BASE MODULE EXTENSION		5. FUNDING NUMBERS C - F30602-94-D-0007 PE - 35139B PR - R533 TA - QJ WU - 26		
6. AUTHOR(S) Paul Bell, David Kolassa, Michael McQuinn, Sandra Stoltz, William Reid, Jason Hamshar, and Christopher Williams				
7. PERFORMING ORGANIZATION NAME(S) AND ADDRESS(ES) Sterling Software Information Technology Division Beaches Technical Campus, Rt 26N Rome NY 13440		8. PERFORMING ORGANIZATION REPORT NUMBER N/A		
9. SPONSORING/MONITORING AGENCY NAME(S) AND ADDRESS(ES) Air Force Research Laboratory/IFEB 32 Brooks Road Rome NY 13441-4114		10. SPONSORING/MONITORING AGENCY REPORT NUMBER AFRL-IF-RS-TR-1998-158		
11. SUPPLEMENTARY NOTES Air Force Research Laboratory Project Engineer: Douglas M. Beridon, 1Lt, USAF/IFEB/(315) 300-2604				
12a. DISTRIBUTION AVAILABILITY STATEMENT Approved for public release; distribution unlimited.		12b. DISTRIBUTION CODE		
13. ABSTRACT (Maximum 200 words) The Global Command and Control Systems (GCCS) is the DoD's primary joint command, control, communications, computer, and intelligence systems. The Joint Mapping Toolkit (JMTK) provides the mapping function to the Core Operating Environment (COE) of the GCCS. JMTK is divided into three primary areas: (1) Visual, (2) Analysis (nonvisual), and (3) Spatial Data Base (SDBM). The primary objective of the SDBM effort is to define, design, develop and test mapping, charting and geodesy (MC&G) spatial data base management and data access software for the inclusion as the SDBM of the GCCS COE JMTK. The SDBM contains the following capabilities: Import NIMA data in standard formats (VPF, RPF, DTED, ITD); archive NIMA data in the original format without reformatting any data (preprocessing); and provide data access and retrieval through the use of public API functions.				
14. SUBJECT TERMS Joint Mapping Toolkit, Global Command and Control System, Spatial Data Base, Mapping, Charting, Geodesy		15. NUMBER OF PAGES 44		16. PRICE CODE
17. SECURITY CLASSIFICATION OF REPORT UNCLASSIFIED	18. SECURITY CLASSIFICATION OF THIS PAGE UNCLASSIFIED	19. SECURITY CLASSIFICATION OF ABSTRACT UNCLASSIFIED	20. LIMITATION OF ABSTRACT UL	

TABLE OF CONTENTS

PREFACE.....	iii
SECTION 1 INTRODUCTION.....	1
1.1 Identification.....	1
1.2 Program Background and Objectives.....	1
1.3 Summary of Accomplishments.....	3
SECTION 2 PROGRAM OVERVIEW	4
2.1 Refinement of the Spatial Data Base Requirements.....	4
2.2 SDBM Extensions Design.....	4
2.3 Implementation of the SDBM Extensions	5
2.4 SDBM Software Testing	5
2.5 SDBM Software Integration.....	6
SECTION 3 SDBM EXTENSIONS DESCRIPTION.....	7
3.1 Spatial Data Base Architecture.....	7
3.2 Application Programmer Interface (API).....	8
3.3 Import Application.....	10
SECTION 4 SDBM EXTENSIONS	11
4.1 Indexing Capability	11
4.2 Transaction Service for Asynchronous Processing.....	12
4.3 Client-Server Architecture	12
4.4 Retrieval of DTED and Application Data.....	13
4.5 Import of Application Data.....	13
SECTION 5 SUMMARY	14
5.1 Results.....	14
5.2 Conclusions.....	14
5.3 Recommendations.....	15
5.4 References	15
5.4.1 Government Documents	15
5.4.2 Non-Government Documents.....	15
APPENDIX A SDBM TEST ANALYSIS.....	A-1
APPENDIX B ACRONYMS.....	B-1
APPENDIX C GLOSSARY.....	C-1

LIST OF FIGURES

NUMBER	TITLE	PAGE
3-1	Spatial Data Base Architecture.....	8
3-2	GCCS JMTK 3.0 Architecture	9
4-1	Parent-Child Node Relationships within an R-Tree.....	11
A-1	SDBM Initialization Test Results.....	A-3
A-2	Connection Services Test Results.....	A-4
A-3	SDBM Data Import Test Results.....	A-6
A-4	Query an SDBM Data Base Test Results	A-7
A-5	Data Base Services Test Results.....	A-8
A-6	SDBM Data Retrieval Test Results.....	A-9
A-7	Data Dictionary Services Test Results	A-10
A-8	Transaction Services Test Results.....	A-11
A-9	Get a Description of an Error Code Test Results.....	A-12

PREFACE

This document presents the Final Technical Report of the Global Command and Control System (GCCS) Spatial Data Base Module (SDBM) Extensions effort sponsored by Rome Laboratory, Contract No. F30602-94-D-0007/Task 20, in accordance with CLIN 0002, ELIN A010. The GCCS SDBM Extensions project focused on enhancements to the design and implementation of the existing SDBM, a geospatial data base supporting the Mapping, Charting, Geodesy, and Imagery (MCG&I) requirements of the GCCS. An initial baseline was implemented and delivered under the contract entitled Global Command and Control System Spatial Data Base Module.

This report is organized into five sections with three appendices. The introductory section identifies the program and provides a background of the effort and the unique objectives that were outlined at the start of the effort. An overview of the specific accomplishments made during the effort is also provided in the introduction. Section 2 provides the details of the technical approach used to achieve the objectives of the effort. A complete description of the Spatial Data Base Module is presented in Section 3 that includes both the data base architecture and the software components to utilize it. In Section 4, we describe the work performed under the effort to support the development of the GCCS/JMTK Extensions. Section 5 ends the report with the results obtained from the development of the SDBM extensions and the conclusions and recommendations.

1Lt. Douglas Beridon was the Rome Laboratory/IRRP project engineer. Mr. Paul Bell was the Sterling Software project manager who directed a project staff that included Mr. David Kolassa, Mr. Michael McQuinn, Ms. Sandra Stoltz, Mr. William Reid, Mr. Jason Hamshar, and Mr. Christopher Williams. The Sterling Software SDBM Extensions project team is grateful for the leadership and technical support provided by 1Lt. Douglas Beridon and RL/IRRP during the course of the effort. We are also grateful to Ms. Cheryl Blake, National Imagery and Mapping Agency (NIMA) for valuable data production and operational insights that helped make this project successful.

SECTION 1 INTRODUCTION

1.1 Identification

This Final Technical Report describes the activities performed by Sterling Software, Information Technology Division under the Rome Laboratory (RL) sponsored program entitled the Global Command and Control System (GCCS)/Spatial Data Base Module (SDBM) Extensions. The project was conducted for the RL Image Products Branch (IRRP) with the end customer being the National Imagery and Mapping Agency. This twelve month effort extended the currently existing SDBM capabilities by refining the SDBM requirements and developing a revised Software Requirements Specification (SRS); developing and implementing a client-server interface to the SDBM; providing the capability to import Interim Terrain Data (ITD)—based on the Standard Linear Format (SLF); creating a data segment for the JMTK as part of the DII COE kernel; providing an indexing scheme for both digital terrain elevation data (DTED) and application defined data to precipitate the access of these data types; and updating the SDBM API and test software.

1.2 Program Background and Objectives

The GCCS is the primary joint command, control, communications, computer and intelligence systems for the United States Department of Defense (DOD). GCCS variants (system and workstation configurations of GCCS compliant software) use applications developed by many formal acquisition programs (e.g., Standard Theater Army Command and Control System, Contingency Theater Air Control System Automated Planning System, and the Operations Support System) to provide an integrated capability at most levels of command. Development of GCCS is managed by the Defense Information Systems Agency (DISA). The GCCS method, architecture, environment, and core software are also used by components of the DOD (e.g., U.S. Navy, U.S. Marine Corps, U.S. Air Force, U.S. Army, DOD Intelligence, NIMA, etc.) for command and control related projects.

Due to the integration philosophy and techniques adapted by GCCS projects, DISA and partner organizations are able to now field more capable systems cost effectively. By standardizing the way the software is built and integrated, duplication of effort is avoided through software reuse. Standardization goes beyond the structure of the software. Use of common software to achieve certain key command and control capabilities not only provides a common interface for client software, but ensures that the user sees predictable behavior and a familiar user interface for capabilities that are found at a variety of command centers. Training requirements are thus reduced and user proficiency is increased. Interoperability also results from ensuring that critical command, control, and intelligence data is processed by the same software regardless of what GCCS variant is being used.

GCCS is not a DOD development program. There is no prime contractor for GCCS. Rather GCCS is a strategy, technique, and set of standards for leveraging the development efforts of a large number of programs, each of which may have one or several development companies and organizations. All participating programs benefit from the work done by other organizations.

As a response to shifting budgetary priorities that have resulted in funding reductions for research and development of new command and control systems, the DOD began using two

development methods that significantly differed from previous practice. The first was evolutionary acquisition or development (EA or ED). A system developed under ED does not go through a laborious specification process before development. Instead, the system is built up and fielded in a series of increments.

The second concept involves application of a "bottom up" rather than "top down" approach. Top down structured analysis breaks the large system into modules. In bottom up analysis, software is integrated up from:

- a common operating environment (COE)
- existing commercial off-the-shelf (COTS) products
- government off-the-shelf (GOTS) software
- newly developed software to satisfy the needs of the user community

This approach to integrating software requires that the software operate in an environment flexible and robust enough to satisfy the resource requirements of a diverse set of computer programs. It also requires that software products be built and selected to conform to a rigorous set of standards ensuring that all applications will come together as one entity.

DISA has decided to consolidate command and control systems under development into a single architecture, making use of a core set of software services. These projects develop application software that will follow strict standards and use common core products for all applicable functions. In taking this approach, software developed by one organization can be incorporated at any type of command center simply by choosing to include it in the installed system. This approach makes optimal use of program resources and increases the capabilities available to the user communities.

GCCS has a binary dynamic library, the COE, as a universal application foundation. The COE is divided into nineteen functional areas, one of which is mapping. This portion is referred to as the Joint Mapping Toolkit (JMTK). The Joint Services Working Group (JSWG) COE for mapping has been formed to guide and facilitate the service members contributing to the JMTK. The JSWG COE members have divided the mapping portion of the COE into three primary areas. These areas are 1) Visual, 2) Analysis (non-visual), and 3) Spatial Data Base. Given the ambitious schedule of the GCCS, the JSWG COE has elected to tap each services' assets to provide functionality to JMTK; Navy's Chart II software to fulfill the Visual; Army's Topographic Evaluation Module (TEM) for the Analysis; and the Air Force's Common Mapping Toolkit (CMTK) for the Spatial Data Base portion. Software modules from all services may well migrate and integrate into all areas of the mapping COE toolkit in due time. These selections are only an initial departure point to construct a mapping COE toolkit which will allow "first-start" functionality for GCCS.

The primary objective of this SDBM effort is to define, design, develop and test mapping, charting and geodesy (MC&G) spatial data base management and data access software for inclusion as the Spatial Data Base Module of the GCCS COE JMTK. The SDBM used the current CMTK MC&G software as the basis for the initial functionality of GCCS.

The current Spatial Data Base as a component of the GCCS COE JMTK contains the following capabilities: import NIMA data in standard formats (VPF, RPF, DTED, ITD); archive NIMA data in the original format without reformatting any data (preprocessing); and provide data access and retrieval through the use of public Application Programmer Interface (API) functions. The information contained in this final report represents a summary of the SDBM

Extensions program background, objectives, technical approach, and functional capabilities of the SDBM Import application, public APIs, the indexing scheme used to support rapid access of the DTED and application defined data, and SDBM client-server functionality performed and developed under this effort.

1.3 Summary of Accomplishments

Six major accomplishments were achieved during the SDBM Extensions contract.

1. The design of the SDBM for compliance with the DII COE.
2. The public and private SDBM API functions were enhanced. The SDBM API has been modified to include nine public API functions. In support of the public API functions, approximately 150 private API functions have also been developed. The API functions were developed and documented according to JMTK Working Group standards. The API Test application and the SDBM Import application were modified to access the enhanced SDBM API functionality.
3. A Spatial Data Base Server was developed and delivered during this effort. The Spatial Data Base Server supports all the services that can be accessed through the SDBM toolkit. The Spatial Data Server is different than the toolkit in that it is designed to specifically run in the DII COE, whereas the SDBM toolkit will not be aware of the DII COE architecture.
4. An indexing capability was implemented to support the quick and efficient access of DTED data and application defined data. The implementation is based upon a balanced R-Tree, where each node represents a spatial area.
5. Support for asynchronous processing implemented. Several of the services within the SDBM are time-consuming in nature, or require lengthy processing time. This contract provided the capability to perform a select set of SDBM functions asynchronously, thus providing the capability to continue processing other tasks while a lengthy task is completing. A transaction process was developed for SDBM under this effort in order to provide the capability to a user to inquire the status of a particular asynchronous process, or to abort a task before processing is complete.
6. A data retrieval capability was developed which provides a retrieval service to obtain geospatial data maintained by the Spatial Data Base Module. RPF data remains retrievable in its native format as it was within the version 3.0 SDBM software. DTED software can be retrieved in its native format or it can be retrieved in a tailored format where the requester can specify the area of interest, the data resolution, the origin of the data, etc. Application defined data is also retrievable through the enhancements made during this effort.

During this contract the following deliverables and technical documentation were delivered: Monthly Status Reports, Software Test Description, Software Test Plan, Configuration Management Plan, GCCS Spatial Data Base Extensions Software Requirements Specification, a Software Design Description Document, SDBM Computer Programmer's Manual, SDBM Software User's Manual, Presentation Materials, and the SDBM Computer Software.

SECTION 2 PROGRAM OVERVIEW

2.1 Refinement of the Spatial Data Base Requirements

Sterling Software performed a review and analysis of the functional requirements document for JMTK, dated 20 July 1995. This analysis led to the development of the current SDBM Software Requirements Specification for the GCCS Spatial Data Base Extensions, dated 23 August 1996. The SDBM Software Requirements Specification Document identifies the JMTK requirements recognized as belonging to the Spatial Data Base Domain of JMTK. These requirements were placed in a logical format flow within the SDBM software requirements specification to establish the specific requirements of the Spatial Data Base Module computer software configuration item (CSCI) of the JMTK.

2.2 SDBM Extensions Design

The SDBM was designed to be one of three architecture components of the JMTK, with the other two components consisting of the Visual Module (displays of maps and overlays), and the Analysis Module (terrain analysis, line of sight, etc.). The objective of the SDBM Extensions Design was to extend the design of the MC&G spatial data base management and data access software of the Spatial Data Base Module of the GCCS COE JMTK.

Sterling Software defined the spatial data base and data access requirements for the GCCS SDBM effort by:

1. Providing assistance and becoming actively involved with the JMTK Working Group to define the API for the Spatial Data Base and Data Access software.
2. Analyzing existing NIMA MCG&I datasets (e.g., CADRG, VMAP Level 0, DTED, etc.) to define data commonalty among the various mapping products and providing proposed solutions to limit and/or eliminate redundant data.

Under this effort, Sterling Software enhanced the design of the GCCS SDBM which was compliant with the GCCS COE Data Management, Data Access, and Data Interchange Services (DIS). This module provided full support for the access and data base management of MCG&I data required by the GCCS JMTK Visual and Analysis modules. This task was achieved by examining and thoroughly understanding the current COE components. Sterling Software also extended the design of the data base management functions for the GCCS SDBM to incorporate the following functionality:

- indexing of the graphical data types DTED and JMTK application defined data
- a client-server interface to the Spatial Data Base toolkit of functions
- retrieval of geospatial data based upon a "tailored" request

The data base management functions designed under this phase for the GCCS SDBM maintained a consistency with the specifications identified within the Functional Specification for the JMTK, as those specifications pertain to the task of data base management for the JMTK and, therefore, the GCCS SDBM. Sterling Software also designed a COE-compliant DIS to import and export MCG&I datasets and associated metadata to and from the GCCS SDBM. The DIS design allowed for the import and export of MCG&I datasets in their native NIMA formats. The DIS design also allowed the datasets to be accessible from the associated storage media of each data type.

2.3 Implementation of the SDBM Extensions

Sterling Software has developed an initial baseline of the Spatial Data Base Module. The initial implementation includes the support of RPF, VPF, DTED, and ITD datasets, and associated metadata. The initial implementation performs the Data Base Management functions, the Data Access Functions, and the Data Interchange Service functions described in Section 2.2 and relevant to the support of the datasets.

All computer software designed and developed for this effort adheres to Mil-Std-498, entitled *Software Development and Documentation*, dated 5 December 1994. Also, all SDBM software APIs have been developed in C. All software delivered under this task is completely maintainable and modifiable with no reliance on any non-delivered computer programs and documentation. All software has been developed and tested under the following platforms and operating systems:

- Sun Workstation – Solaris 2.4, SunOS 4.1.3
- Hewlett Packard – HP-UX 10.10

All JMTK software components are compatible with the following commercial and public software versions:

- X11 R5
- OSF Motif 1.2.2

2.4 SDBM Software Testing

The GCCS SDBM software has undergone rigorous testing throughout the development cycle of this effort. Modularized software has been tested thoroughly by each engineer responsible for a particular unit/portion of software that was developed before it was integrated into the baseline of SDBM. The baseline SDBM was also thoroughly tested on a regular basis to ensure that incorporation of a software module did not affect the functionality of the SDBM.

Sterling Software performed extensive tests on all capabilities of the GCCS SDBM enhancements to verify that all requirements for the effort were met. A Software Test Description document was written to describe the format of the test plan, test descriptions, and test procedures for the GCCS SDBM Extensions effort. Upon installation of the GCCS SDBM Extensions software at the designated Government facility, the software test was repeated in accordance with the Software Test Description document.

To ensure that the SDBM API functions were fully operational, a software testing tool was developed. The ApiTest Tool was developed to test each API function before it was integrated into the SDBM. The ApiTest Tool allowed for all tests to be performed in a controlled environment using predesignated steps and inputs, to produce results that could be observed and evaluated.

The formal test procedures were conducted at Sterling Software's facility in Rome, New York in August of 1997. The test procedures were conducted by a Sterling Software engineer and witnessed by the GCCS SDBM Extensions project engineer from Rome Laboratory/IRRP, Lieutenant Beridon, and an additional Government employee from Rome Laboratory. All tests were performed to the satisfaction of Government attendees. A Software Test Plan was also written and provided to the Government in order to specify the exact times, dates, locations, etc., at which the formal test procedures were conducted.

2.5 SDBM Software Integration

The GCCS SDBM software has undergone multiple integration steps through its life cycle. Sterling Software supported all integration activities in accordance with the GCCS Integration Standard. The following identifies the main areas of integration that Sterling Software has supported:

- integration of the MCG&I data server into the GCCS COE
- integration of all SDBM APIs and functional software into the GCCS JMTK

Sterling Software provided continuous support in the above areas throughout the SDBM task. In assisting in the integration effort of the GCCS SDBM, Sterling Software used the Telnet communication capabilities that were established during initial phases of the SDBM effort. The communications configuration has proven to be a highly efficient method of integration, trouble shooting, and maintenance support for this effort.

Also, during this effort Sterling Software engineers performed on-site integration support at the JMTK System Integrator's facility, when needed, in order to facilitate the integration of the SDBM software segment into the JMTK baseline.

SECTION 3 SDBM EXTENSIONS DESCRIPTION

The Joint services have previously developed and maintained their own software products to support MCG&I requirements. Although functionality is shared by the individual mapping applications, each implementation is unique. To provide the Joint services with a set of common capabilities and a common implementation, the GCCS program is working towards the development of a COE. MCG&I is just one of many functional areas within the COE architecture being addressed by the development of a Joint Mapping Toolkit.

The JMTK is being developed as a collection of APIs that enable support applications to interface with MCG&I functionality. Version 3.2 of the JMTK is comprised of three distinct modules: the Visual Module, which provides map presentation functionality; the Analysis Module, which performs geospatial computations; and the Spatial Data Base Module, which provides the geospatial data management services.

The Spatial Data Base Module operates in two modes, interactive and client-server. The interactive mode supports all the user directed activities required by the Spatial Data Base Module within a stand-alone application. This includes the capabilities to import, manage, and export the data. The client-server mode encompasses the same activities, but in a client-server environment where the server has access to the JMTK and one or more clients can import, manage, and export data to/from a JMTK environment.

The following sections of this Final Technical Report describe the Spatial Data Base architecture, the set of API functions provided by version 3.2 of JMTK, and the Spatial Data Import Application developed to provide a means of populating a spatial data base.

3.1 Spatial Data Base Architecture

The Spatial Data Base Module architecture is based on a hierarchical directory structure of metadata. This structure effectively remains the same as it has in previous deliveries of the SDBM software, with minor modifications made to enhance the metadata. Figure 3-1 depicts this Spatial Data Base metadata directory structure. Three levels of metadata summarize the actual standard NIMA data. The metadata does not contain any actual data within the structure: it simply describes the data and provides information as to where the data is physically located on the system.

Level 1 metadata provides an overview of the entire data base. Each data base is named at creation. The action of creating a new data base causes a directory structure to be built within the Spatial Data Base environment. The directory is labeled with the data base name and an initial metadata structure is placed within that directory. This metadata structure is continually updated as datasets are added to the data base. A format directory (i.e., VPF, RPF GRD, SLF) is added beneath the data base directory each time a new format is presented for import. No metadata is associated with this directory level.

Level 2 metadata contains information describing volume metadata (i.e., DCW, CADRG, DTED, ITD) and all datasets of a particular volume. Each time a new data type or volume of data is imported into the data base, a directory is built beneath the appropriate Format directory to indicate the new data type. The metadata at the volume level and at the data base level are updated to reflect the addition of the new data.

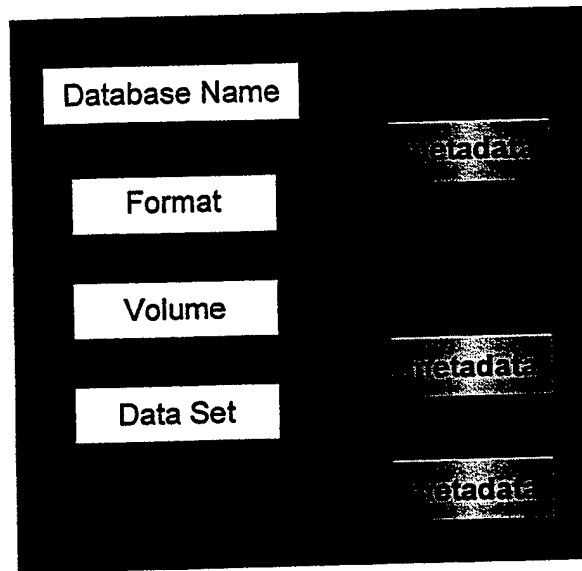


Figure 3-1. Spatial Data Base Architecture

Level 3 metadata contains information describing a particular dataset which has been imported into a particular data base. As a new dataset is imported into a data base, a directory structure is built beneath the appropriate volume directory and all three levels of metadata are updated accordingly.

For the JMTK 3.2 delivery, a dataset is equivalent to:

- a. a compact disk (CD) distributed by NIMA containing a standard NIMA product, such as VPF, RPF, DTED;
- b. an 8mm tape, such as that containing ITD data that can be copied to a disk; or,
- c. a file found on a disk (e.g., application data)

Prior to the import process, the data in CD format can reside on the CD itself, or may be copied to hard disk. Future versions of JMTK will allow a dataset to represent a portion of data taken from a CD. ITD data distributed on 8mm tape must first be loaded onto a disk. The data referenced by the metadata can remain on CD or it can be placed on hard disk during the import process for JMTK 3.2.

The three levels of metadata within the Spatial Data Base architecture will develop and mature, providing additional information about the actual data as future releases of JMTK develop and mature.

3.2 Application Programmer Interface (API)

As depicted in Figure 3-2, the API for JMTK provides a means of interaction between common and service specific applications and a JMTK environment. The JMTK environment consists of the three distinct modules, the Visual Module, the Analysis Module, and the Spatial Data Base Module. The set of module-related API-level functions have been enhanced and extended for each of these modules within the JMTK 3.2 release to provide a common and consistent view of the battlefield to all military players. Future versions of JMTK will build upon this enhanced baseline to provide additional functionality in increments, as the enhancements did for this delivery.

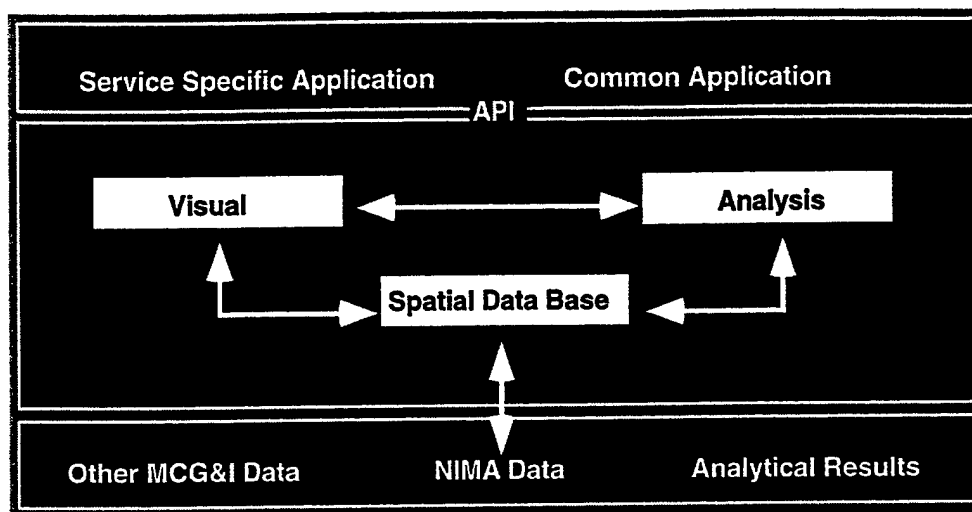


Figure 3-2. GCCS JMTK 3.0 Architecture

Nine public API functions have been delivered to provide access to the Spatial Data Base Module functionality. Approximately 150 private API functions have been delivered in support of these nine public APIs. All the APIs have been developed and documented in accordance with the JMTK Working Group Standards.

The following is a brief description of the public APIs provided for interaction with the Spatial Data Base Module of JMTK 3.2:

JMS_SdbInit	Initializes the connection structures and sets global values used throughout the SDBM.
JMS_ConnectService	Establishes or terminates a connection with the Spatial Data Base Module and sets or retrieves connection preferences.
JMS_DataStore	Stores MCG&I data or application data in a JMTK spatial data base.
JMS_DbQuery	Queries the contents of spatial data holdings managed by the Spatial Data Base Module.
JMS_DataRetrieve	Retrieves data from a spatial data base.
JMS_DbService	Provides the capability to create and manage JMTK spatial data bases.
JMS_DDService	Provides SDBM and application data dictionary services.
JMS_TransactionService	Retrieves the status and percentage of completion for a specified transaction identifier and cancels specified transactions.
JMS_ErrorGet	Retrieves the text message for the specified error code.

3.3 Import Application

The SDBM Import application was enhanced during this effort. The application provides the JMTK Spatial Data Base Module developers with a means of populating a Spatial Data Base in the context of a JMTK environment. It also provides a valuable means for testing the API-level functions required for the JMTK 3.2 delivery. SDBM Import users can use the application to create new data bases, import standard NIMA data to a data base, and perform spatial data base management functions.

Several enhancements were made to the SDBM Import application during the SDBM Extensions contract. The most evident of the SDBM Import application modifications are the enhancements made to exercise the JMTK 3.2 SDBM API. Additionally, the presentation screens were modified slightly to provide a more flexible screen layout. This was done with the expectation that future versions of JMTK will be using the SDBM Import application and will want to easily expand the interface to accommodate new capabilities. Currently, two of the main screen panels are implemented and functional for the SDBM Import application 3.2 release. The Import Panel provides the SDBM user with the capability to import standard NIMA products into an SDBM data base. The Data Management Panel allows the user to perform data base management functions such as creating and deleting an SDBM data base, and copying, moving, backing up a data base, etc.

It is expected that this application will evolve into an SDBM developer's tool in future versions of JMTK. The software provides a baseline tool which can be expanded accordingly to assist in the development of additional API-level functions, provide a resource for testing functionality, provide a resource for regression testing, and provide a method for quickly populating a Spatial Data Base for future versions of JMTK.

SECTION 4 SDBM EXTENSIONS

4.1 Indexing Capability

The SDBM Extensions effort provided the capability within SDBM to index both DTED and application defined data. The indexing mechanism is used to expedite the retrieval process for both of these data types.

The indexes are created and maintained using an R-Tree. In this application, the R-Tree is a balanced tree data structure where each node represents a spatial area as a minimum bounding rectangle. The child nodes represent the actual data being indexed while the parent node is a superset of its children. Figure 4-1 shows the child nodes of the spatial areas a, b, c, and d and how they correspond with the parent nodes of the larger spatial areas AA and BB. This implementation will provide for a quick and efficient search of the spatial data maintained within the SDBM.

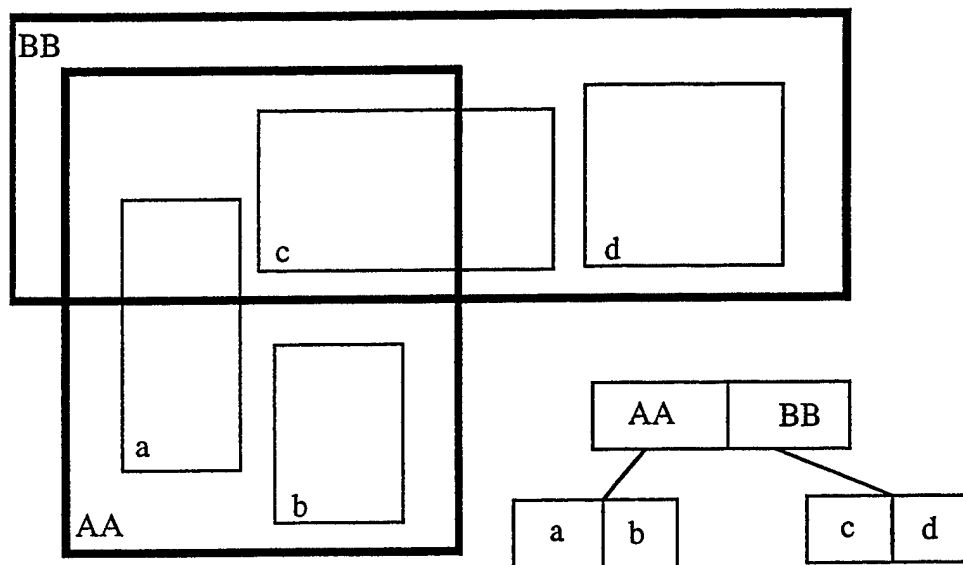


Figure 4-1. Parent-Child Node Relationships within an R-Tree

The indexing scheme used in SDBM initially builds an index file for each data format as it is imported into an SDBM data base. A master index list of pathnames to the lowest level of the data maintained within the SDBM (i.e., frames, files, tiles) is also created. One master index file will exist for each data base. The data format index file and the master index list are used together to build an index file that resides in memory as an application accessing the SDBM is operating. It is the memory resident index file that is accessed to provide pathnames to the data indexed, as requested.

The indexing mechanism consists of three functional areas:

1. Construction of the index file(s) for a unique data base connection.
2. Maintenance of the index file(s).
3. Retrieval of the pathnames for a particular subset of data using the index file(s).

The construction of an index file is performed when a connection to the SDBM is requested. An index is built by first checking whether any index files exist for the data bases specified for a particular connection. A check is then made to identify whether any data resides within those index files for the area of interest (AOI) specified. The index built will reside in memory for a particular connection ID only. This in-memory index will be used by the data retrieve function.

The maintenance of the index files occurs during the import process of SDBM. When data is imported, the AOI of the data is inserted into the index file along with a file offset in the master index file which indicates where the path to that segment of data can be found. This is performed for each lowest level representation of the data (i.e., frame, file, or tile) that is being imported. This delivery of SDBM supports the indexing of DTED and application defined data. Future releases of SDBM will support the indexing of additional data types.

The index retrieve function searches an index for a particular connection and returns the exact path(s) to the data that matches the criteria provided in the SDBM retrieve request. The index retrieve function will search the in-memory index by AOI. If the AOI requested intersects with the AOI represented by the index file, the offset in the master index file will be given and the pathname will be extracted from that file. This pathname will then indicate to the SDBM retrieval function the file, or files, that contain the actual map data. The SDBM retrieval function will use the pathname(s) to return the actual requested map data, or will use the pathname to access the data for further processing.

The indexing algorithm used is based on original test code written by Toni Guttman and later ported to ANSI C on a variety of platforms by Daniel Green. The software has been modified to function within the guidelines of the SDBM implementation and software coding standards.

4.2 Transaction Service for Asynchronous Processing

Several functions within the SDBM API perform tasks which require lengthy processing times. To free up the system processor for other processing, an asynchronous background tasking method was implemented. This method was employed as part of the SDBM Extensions effort through the use of system calls to create new child processes. SDBM API functions which support asynchronous processing for the SDBM 3.2 delivery include JMS_DataStore and JMS_DbService.

A transaction process was developed which provides the opportunity for an SDBM user to determine the status of an asynchronous task. The user can continue with his/her activities within an SDBM application while an asynchronous process is performing the requested task, yet have a means to obtain the status of that asynchronous task at a later time. When an asynchronous task is executed, the user receives a transaction identifier indicating the task. Through the use of the SDBM API function, JMS_TransactionService, the user can inquire the status of the process identified by the transaction identifier. The status returned would indicate the portion of the task complete (percentage) or an error.

4.3 Client-Server Architecture

The SDBM was designed and enhanced under the SDBM Extensions effort to run both as a client-server architecture and as a library or toolkit of functions that a stand-alone application would include and exercise within the application environment. The client-server architecture was built using remote procedure call (RPC) communications.

In the context of the client-server environment, the SDBM Server was designed and built to use the SDBM toolkit of functions. The SDBM Server would include the toolkit library exactly as a stand-alone application in order to access the SDBM API. A client application would call the same SDBM API. However, the API function call in the client-server configuration actually packages up the parameters passed to the API and provides the package to the Server to unpack and make the actual call to the SDBM API. In effect, the client is calling the SDBM API, but using the RPC to access an SDBM server to obtain the results of an SDBM API function call.

Both the toolkit and the client-server architectures support the capability to perform asynchronous processing of time-consuming SDBM tasks. The client and the server software function on both the Solaris and the HP-UX operating systems.

4.4 Retrieval of DTED and Application Data

The SDBM software was enhanced under the effort to provide a capability to retrieve spatial data from an SDBM data base. The SDBM Extensions effort was able to achieve this capability for the DTED and application defined data types. These data types are capable of being retrieved from within an SDBM data base in either a native format or, in the case of DTED data, a tailored format defined by the application as part of the retrieval request. The SDBM software will be enhanced in future releases of SDBM to include the retrieval of additional data types. Future releases will also provide the capability to retrieve the data types as a composite map image of the requested spatial data. This will return the data as a raster image for display.

For version 3.2 of the SDBM software, an application requesting data will provide a data type as part of the request. The data type parameter is used to indicate the type of data to be returned. This version of the software will recognize DTED Levels 0, 1, and 2 for retrieval of the DTED product. Application data can be retrieved by setting the data type parameter equal to the name used to register the application data type.

The application will also indicate whether the data is to be returned in a native format, "as is," or in a tailored format. If the user specifies a tailored format, the user will also provide a frame size; whether the data should be returned on row major or column major order; whether the origin of the data returned should be the lower left or upper left; and an elevation interval (resolution) of the data to be returned. The data is returned to the requester a frame (a file) at a time. A count argument has been provided with this request to indicate the number of frames (files) remaining upon receiving a frame.

4.5 Import of Application Data

The SDBM Extensions effort provides the capability within the SDBM to import application defined data. Application data can take any form. Examples include analysis results, spatial data base map layers, a JMTK map display state used to recreate a particular display, perspective scene parameters, etc.

Each application data type must be registered with the SDBM prior to the import process taking place. This can be accomplished through the SDBM API function JMS_DbService, thus providing a means for that data type to be recognized by the import process of SDBM. A Data Dictionary will be maintained for each registered application defined data type. Metadata fields can be added to the application data's data dictionary through the JMS_DDService API. At import, the application defined data will be stored as a single file into a data base identified in the import process argument list under a directory having the same name as the registered data type.

SECTION 5 SUMMARY

5.1 Results

The initial task of the SDBM Extensions effort consisted of an in-depth review and analysis of the functional requirements document for JMTK, dated 20 July 1995. Sterling Software used the results of this analysis to develop the SDBM Software Requirements Specification for the GCCS Spatial Data Base Module Extensions document, dated 23 August 1996. The requirements identified within this document, along with direction from NIMA, guided the implementation process for the SDBM Extensions effort.

Subsequent tasking included enhancements to the SDBM software to develop a client-server architecture for the SDBM software, while not preventing the software from running within a stand-alone application. An indexing capability was also provided to support the retrieval of the native geospatial data in a timely fashion. Enhancements to the retrieval process were made to support the retrieval of application defined data and the retrieval of a tailored geospatial request. Lengthy processing tasks within the SDBM were modified to perform asynchronously so as to continue processing within an SDBM application while a particular asynchronous task is completing. In support of the asynchronous processing, a transaction service was implemented to provide a means by which to query the status of a particular asynchronous task.

In support of these modifications to SDBM, updates were made to the SDBM API. These modifications were described in the SDBM API documentation and provided to NIMA as part of the SDBM Extensions effort. Enhancements were made to the Spatial Data Base Manager and the ApiTester applications as well. Both applications were modified to incorporate the new SDBM functionality and the modifications made to the SDBM API.

5.2 Conclusions

The accomplishments achieved during this effort provide insight into the development of modular geospatial data access capabilities. Past implementations have often resulted in systems where it is difficult to upgrade functionality without a major software overhaul. The SDBM demonstrates that it is feasible to create modular software that can interface application programs with the diverse array of geospatial information in a straight forward manner. The complexity of accessing and retrieving data can be hidden from the applications offering developers a simple API to work with.

A general architectural goal of the JMTK is "plug-and-play" components. The SDBM was consequently designed to be a stand-alone module within JMTK. The lack of function calls to any other JMTK module enables the SDBM to be a true "plug-and-play" capability. In addition, the analysis of geospatial requirements produced an API that is relatively small in size but has been defined to support all stated JMTK spatial access requirements. Thus the SDBM can be upgraded as required without impact to other JMTK modules and/or mission applications that make calls to it directly. Furthermore, this "plug-and-play" capability has been implemented in such a way as to support both tool kit implementation and/or a client/server environments.

Performance has always been a consideration and is of paramount importance regarding the access of geospatial information. Methods for organizing, accessing, and retrieving individual

elements and tailored data products were researched. The chosen indexing method that was integrated within the SDBM was applied to the retrieval of elevation data. The improved performance in DTED retrieval over the previous SDBM release demonstrates that indexing will continue to be an integral component of spatial data base management.

In conclusion, we have learned from this effort that modular software for geospatial data access and retrieval is possible to build. The plug and play approach is a viable architecture for the JMTK and will support NIMA's long range goals of providing MCG&I capability through COTS solutions. Furthermore, as the SDBM evolves to provide capabilities to more complex data sets, such as VPF, the indexing capability will be critical element in the overall performance.

5.3 Recommendations

As this contract demonstrated, enhancements are necessary to continue to evolve any system. Several recommendations have been made for enhancing the GCCS SDBM data access functionality and the overall design and development of the system. The following specific recommendations have been noted to take the SDBM to the next step and to expand upon the enhancements made during this effort:

1. Incorporate additional data types into the import and retrieval processes.
2. Provide an indexing scheme to support the data retrieval of RPF, VPF, SLF and other data types.
3. Expand the Spatial Data Base Manager application to provide a useful tool to the Spatial Data Base user/administrator.
4. Enhance the SDBM software so that it is compatible with Windows NT.
5. Ensure that follow-on contracts make allowances for some on-site integration support time.

5.4 References

The following reference documents have been used in the generation of this document.

5.4.1 Government Documents

Content Standard for Digital Geospatial Metadata, Federal Geographic Data Committee, 8 June 1994.

5.4.2 Non-Government Documents

Software Requirements for the GCCS Spatial Data Base Module Extensions, Sterling Software/ITD, 23 August 1996.

Software Programmer's Manual for the Joint Mapping Toolkit/Spatial Data Base Module, Sterling Software/ITD, 15 September 1997.

Software User's Manual for the Joint Mapping Toolkit/Spatial Data Base Module, Sterling Software/ITD, 15 September 1997.

Software Test Plan for the Joint Mapping Toolkit/Spatial Data Base Module, Sterling Software/ITD, 15 September 1997.

Software Test Description for the Joint Mapping Toolkit/Spatial Data Base Module, Sterling Software/ITD, 15 September 1997.

CM Plan for the GCCS Spatial Data Base Module, Sterling Software/ITD, 8 August 1996.

Software Engineering Standards for the GCCS Joint Mapping Toolkit, Joint Mapping Toolkit Working Group, 14 November 1995.

APPENDIX A SDBM TEST ANALYSIS

A.1 Identification

This appendix summarizes and evaluates the results of testing the Spatial Data Base Module (SDBM) Computer Software Configuration Item (CSCI) of the Joint Mapping Toolkit (JMTK) for the SDBM Extensions effort.

A.2 Test Overview

The demonstration of the functionality of the JMTK SDBM CSCI version 3.2 was conducted at Sterling Software/ITD, Beeches Technical Campus, Route 26N, Rome, New York. The execution of the Formal Qualification Tests (FQT) was held on August 7, 1997, witnessed by an Air Force representative of Rome Laboratory. The hardware and software configuration used during the FQT is detailed below.

The FQTs consist of:

1. SDBM Initialization
2. Connection Services
 - a) Connect to a data base
 - b) Set connection preferences
 - c) Get connection preferences
 - d) Disconnect
3. SDBM Data Import
 - a) Import VPF product from CD-ROM
 - b) Import RPF product from CD-ROM
 - c) Import DTED product from CD-ROM
 - d) Import VPF product from disk
 - e) Import RPF product from disk
 - f) Import DTED product from disk
 - g) Import application defined data from disk
4. Query an SDBM data base
 - a) Query SDBM data base names
 - b) Query SDBM pathnames
5. Data Base Services
 - a) Create a data base
 - b) Register a new format type
6. SDBM Data Retrieval
 - a) Retrieve native DTED data
 - b) Retrieve application defined data
 - c) Retrieve tailored DTED data
7. Data Dictionary Services
 - a) Retrieve list of data dictionaries
 - b) Retrieve list of elements from a data dictionary
 - c) Retrieve data dictionary element
 - d) Add element to user defined data dictionary
8. Transaction Services
 - a) Get transaction state

- b) Cancel a transaction
- 9. Get a Description of an Error Code

Demonstration Test Record

Hardware Configuration: Sun SPARC IPC

Software Configuration: SunOS version 5.5.1 (Solaris 2.5.1)
TRITEAL Corporation Common Desktop Environment (CDE)
Motif 1.2.2
X11R5
SDBM version 3.2

Location: Sterling Software
Information Technology Division
Rome, New York

Testing Dates: August 7, 1997

Attendees: Lieutenant Douglas Beridon, USAF Rome Laboratory
Captain William Hart, USAF Rome Laboratory
Mr. Christopher D. Williams, Sterling Software/ITD

Formal Test 1, SDBM Initialization:

- **SDBM Initialization Summary**

The SDBM Initialization test was designed to demonstrate SDBM's capability to initialize an SDBM connection and hand back a connection ID which an SDBM user will use to identify a connection for all subsequent services. The table depicted in Figure A-1 summarizes the results of this test.

- **SDBM Initialization Record**

The date, location, test personnel, and witnesses are listed at the beginning of Section A.2, Test Overview.

Formal Test 1 SDBM Initialization	Success	Failure/Errors	Remarks
Initialize an SDBM Data Base	X	None	None

Figure A-1. SDBM Initialization Test Results

Formal Test 2, Connection Services:

a) Connect to a Data Base

The Connect to a Data Base test was designed to demonstrate SDBM's capability to connect to an existing data base maintained by SDBM. The table depicted in Figure A-2 summarizes the results of this test.

- **Connection Service; Connect to a Data Base Record**

The date, location, test personnel, and witnesses are listed at the beginning of Section A.2, Test Overview.

b) Set Connection Preferences

The Set Connection Preferences test was designed to demonstrate SDBM's capability to set the connection preferences to a currently existing data base connection. The test consists of setting the AOI and the data base(s) that will be used throughout the connection. The table depicted in Figure A-2 summarizes the results of this test.

- **Connection Service, Set Connection Preferences Record**

The date, location, test personnel, and witnesses are listed at the beginning of Section A.2, Test Overview.

c) Get Connection Preferences

The Get Connection Preferences test was designed to demonstrate SDBM's capability to obtain the current connection settings for a particular connection. The test consists of providing a connection ID and obtaining the current AOI and the data base(s) that will be used throughout the connection. The table depicted in Figure A-2 summarizes the results of this test.

- **Connection Service, Get Connection Preferences Record**

The date, location, test personnel, and witnesses are listed at the beginning of Section A.2, Test Overview.

d) Disconnect

The Disconnect test was designed to demonstrate SDBM's capability to release a current connection to an SDBM data base. The table depicted in Figure A-2 summarizes the results of this test.

- **Connection Service, Disconnect Record**

The date, location, test personnel, and witnesses are listed at the beginning of Section A.2, Test Overview.

Formal Test 2 Connection Services	Success	Failure/Errors	Remarks
a) Connect to a Data Base	X	None	None
b) Set Connection Preferences	X	None	None
c) Get Connection Preferences	X	None	None
d) Disconnect	X	None	None

Figure A-2. Connection Services Test Results

Formal Test 3, SDBM Data Import:

a) Import VPF product from CD-ROM

The Import VPF product from CD-ROM test was designed to demonstrate the SDBM's capability to import NIMA Vector Product Format data from a CD-ROM into an existing SDBM data base. The table depicted in Figure A-3 summarizes the results of this test.

- SDBM Data Import; Import VPF product from CD-ROM Record

The date, location, test personnel, and witnesses are listed at the beginning of Section A.2, Test Overview.

b) Import RPF product from CD-ROM

The Import RPF product from CD-ROM test was designed to demonstrate the SDBM's capability to import NIMA Raster Product Format data from a CD-ROM into an existing SDBM data base. The table depicted in Figure A-3 summarizes the results of this test.

- SDBM Data Import, Import RPF product from CD-ROM Record

The date, location, test personnel, and witnesses are listed at the beginning of Section A.2, Test Overview.

c) Import DTED product from CD-ROM

The Import DTED product from CD-ROM test was designed to demonstrate the SDBM's capability to import NIMA Digital Terrain Elevation Data from a CD-ROM into an existing SDBM data base. The table depicted in Figure A-3 summarizes the results of this test.

- SDBM Data Import, Import DTED product from CD-ROM Record

The date, location, test personnel, and witnesses are listed at the beginning of Section A.2, Test Overview.

d) Import VPF product from disk

The Import VPF product from disk test was designed to demonstrate the SDBM's capability to import NIMA Vector Product Format data from a disk where the data had previously been copied to, into an existing SDBM data base. The table depicted in Figure A-3 summarizes the results of this test.

- SDBM Data Import, Import VPF product from disk Record

The date, location, test personnel, and witnesses are listed at the beginning of Section A.2, Test Overview.

e) Import RPF product from disk

The Import RPF product from disk test was designed to demonstrate the SDBM's capability to import NIMA Raster Product Format data from a disk where the data had previously been copied to, into an existing SDBM data base. The table depicted in Figure A-3 summarizes the results of this test.

- SDBM Data Import, Import RPF product from disk Record

The date, location, test personnel, and witnesses are listed at the beginning of Section A.2, Test Overview.

f) Import DTED product from disk

The Import DTED product from disk test was designed to demonstrate the SDBM's capability to import NIMA Digital Terrain Elevation Data from a disk where the data had previously been copied to, into an existing SDBM data base. The table depicted in Figure A-3 summarizes the results of this test.

- SDBM Data Import, Import DTED product from disk Record

The date, location, test personnel, and witnesses are listed at the beginning of Section A.2, Test Overview.

g) Import Application defined data from disk

The Import Application defined data from disk test was designed to demonstrate the SDBM's capability to import data provided to SDBM through a JMTK application into an existing SDBM data base. The table depicted in Figure A-3 summarizes the results of this test.

- SDBM Data Import, Import Application defined data from disk Record

The date, location, test personnel, and witnesses are listed at the beginning of Section A.2, Test Overview.

Formal Test 3 SDBM Data Import	Success	Failure/Errors	Remarks
a) Import VPF product from CD-ROM	X	None	None
b) Import RPF product from CD-ROM	X	None	None
c) Import DTED product from CD-ROM	X	None	None
d) Import VPF product from disk	X	None	None
e) Import RPF product from disk	X	None	None
f) Import DTED product from disk	X	None	None
g) Import Application defined data from disk	X	None	None

Figure A-3. SDBM Data Import Test Results

Formal Test 4, Query an SDBM Data Base:

a) Query SDBM Data Base Names

The Query SDBM Data Base Names test was designed to demonstrate the SDBM's capability to query SDBM for a list of possible data bases. The table depicted in Figure A-4 summarizes the results of this test.

- **Query an SDBM Data Base, Query SDBM Data Base Names Record**

The date, location, test personnel, and witnesses are listed at the beginning of Section A.2, Test Overview.

b) Query SDBM Pathnames

The Query SDBM Pathnames test was designed to demonstrate the SDBM's capability to provide a list of paths to available datasets matching input criteria from the Query SDBM Pathnames request. The table depicted in Figure A-4 summarizes the results of this test.

- **Query an SDBM Data Base, Query SDBM Pathnames Record**

The date, location, test personnel, and witnesses are listed at the beginning of Section A.2, Test Overview.

Formal Test 4 Query an SDBM Data Base	Success	Failure/Errors	Remarks
a) Query SDBM Data Base names	X	None	None
b) Query SDBM Pathnames	X	None	None

Figure A-4. Query an SDBM Data Base Test Results

Formal Test 5, Data Base Services:

a) Create a Data Base

The Create a Data Base test was designed to demonstrate the SDBM's capability to create a new SDBM data base within the SDBM environment. The table depicted in Figure A-5 summarizes the results of this test.

- **Data Base Services, Create a Data Base Record**

The date, location, test personnel, and witnesses are listed at the beginning of Section A.2, Test Overview.

b) Register a new format type

The Register a new format type test was designed to demonstrate the SDBM's capability to allow users to register a new data type recognized within SDBM and to provide the identification criteria for recognition. The table depicted in Figure A-4 summarizes the results of this test.

- **Data Base Services, Register a new format type Record**

The date, location, test personnel, and witnesses are listed at the beginning of Section A.2, Test Overview.

Formal Test 5 Data Base Services	Success	Failure/Errors	Remarks
a) Create a Data Base	X	None	None
b) Register a new format type	X	None	None

Figure A-5. Data Base Services Test Results

Formal Test 6, SDBM Data Retrieval:

a) Retrieve Native DTED data

The Retrieve Native DTED data test was designed to demonstrate the SDBM's capability to provide DTED data to a requester in its native format, based upon the parameters provided in the request. The table depicted in Figure A-6 summarizes the results of this test.

- **SDBM Data Retrieval, Retrieve Native DTED data Record**

The date, location, test personnel, and witnesses are listed at the beginning of Section A.2, Test Overview.

b) Retrieve Application Defined data

The Retrieve Application Defined data test was designed to demonstrate the SDBM's capability to provide Application defined data to a requester based upon the parameters provided in the request. The table depicted in Figure A-6 summarizes the results of this test.

- **SDBM Data Retrieval, Retrieve Application Defined data Record**

The date, location, test personnel, and witnesses are listed at the beginning of Section A.2, Test Overview.

c) Retrieve Tailored DTED data

The Retrieve Tailored DTED data test was designed to demonstrate the SDBM's capability to provide DTED data to a requester in a tailored format, based upon the specifications provided by the requester (i.e., point of origin of the data, resolution of the data, etc.). The table depicted in Figure A-6 summarizes the results of this test.

- **SDBM Data Retrieval, Retrieve Tailored DTED data Record**

The date, location, test personnel, and witnesses are listed at the beginning of Section A.2, Test Overview.

Formal Test 6 SDBM Data Retrieval	Success	Failure/Errors	Remarks
a) Retrieve native DTED data	X	None	None
b) Retrieve Application defined data	X	None	None
c) Retrieve Tailored DTED data	X	None	None

Figure A-6. SDBM Data Retrieval Test Results

Formal Test 7, Data Dictionary Services:

a) Retrieve List of Data Dictionaries

The Retrieve List of Data Dictionaries test was designed to demonstrate the SDBM's capability to provide a list of the Data Dictionaries available within a data base. The table depicted in Figure A-7 summarizes the results of this test.

- **Data Dictionary Services, Retrieve List of Data Dictionaries Record**

The date, location, test personnel, and witnesses are listed at the beginning of Section A.2, Test Overview.

b) Retrieve List of Elements from a Data Dictionary

The Retrieve List of Elements from a Data Dictionary test was designed to demonstrate the SDBM's capability to provide a list of elements defined in a particular Data Dictionary. The table depicted in Figure A-7 summarizes the results of this test.

- **Data Dictionary Services, Retrieve List of Elements from a Data Dictionary Record**

The date, location, test personnel, and witnesses are listed at the beginning of Section A.2, Test Overview.

c) Retrieve Data Dictionary Element

The Retrieve Data Dictionary Element test was designed to demonstrate the SDBM's capability to provide a definition of a particular Data Dictionary Element given the Data Dictionary and Element name. The table depicted in Figure A-7 summarizes the results of this test.

- **Data Dictionary Services, Retrieve Data Dictionary Element Record**

The date, location, test personnel, and witnesses are listed at the beginning of Section A.2, Test Overview.

d) Add Element to User Defined Data Dictionary

The Add Element to User Defined Data Dictionary test was designed to demonstrate the SDBM's capability to add a new element to a particular Data Dictionary. The table depicted in Figure A-7 summarizes the results of this test.

- **Data Dictionary Services, Add Element to User Defined Data Dictionary Record**

The date, location, test personnel, and witnesses are listed at the beginning of Section A.2, Test Overview.

Formal Test 7 Data Dictionary Services	Success	Failure/Errors	Remarks
a) Retrieve List of Data Dictionaries	X	None	None
b) Retrieve List of Elements from a Data Dictionary	X	None	None
c) Retrieve Data Dictionary Element	X	None	None
d) Add Element to User Defined Data Dictionary	X	None	None

Figure A-7. Data Dictionary Services Test Results

Formal Test 8, Transaction Services:

a) Get Transaction State

The Get Transaction State test was designed to demonstrate the SDBM's capability to provide a status to the requester regarding the state of a particular ongoing task. The table depicted in Figure A-8 summarizes the results of this test.

- **Transaction Services, Get Transaction State Record**

The date, location, test personnel, and witnesses are listed at the beginning of Section A.2, Test Overview.

b) Cancel Transaction

The Cancel Transaction test was designed to demonstrate the SDBM's capability to allow an SDBM user to cancel the processing of a currently ongoing task. The table depicted in Figure A-8 summarizes the results of this test.

- **Transaction Services, Cancel Transaction Record**

The date, location, test personnel, and witnesses are listed at the beginning of Section A.2, Test Overview.

Formal Test 8 Transaction Services	Success	Failure/Errors	Remarks
a) Get Transaction State	X	None	None
b) Cancel a Transaction	X	None	None

Figure A-8. Transaction Services Test Results

Formal Test 9, Get a Description of an Error Code:

a) Get Error

The Get Error test was designed to demonstrate the SDBM's capability to provide a textual description of a particular error code. The table depicted in Figure A-9 summarizes the results of this test.

• Get a Description of an Error Code, Get Error

The date, location, test personnel, and witnesses are listed at the beginning of Section A.2, Test Overview.

Formal Test 9 Get a Description of an Error Code	Success	Failure/Errors	Remarks
a) Get Error	X	None	None

Figure A-9. Get a Description of an Error Code Test Results

APPENDIX B ACRONYMS

ADRG	ARC Digitized Raster Graphics
ADRI	ARC Digitized Raster Imagery
AFMSS	Air Force Mission Support System
AOI	Area-of-Interest
API	Application Programmer Interface
C3I	Command, Control, Communications, and Intelligence
C4I	Command, Control, Communications, Computers, and Intelligence
CADRG	Compressed ARC Digital Raster Graphics
CD	Compact Disk
CD-ROM	Compact Disk-Read Only Memory
CDE	Common Desktop Environment
CIB	Controlled Image Base
CM	Configuration Management
CMIC	Common Mapping Interface Control
CMS	Common Mapping Standard
CMTK	Common Mapping Toolkit
COE	Common Operating Environment
COTS	Commercial-Off-The-Shelf
CSCI	Computer Software Configuration Item
DCW	Digital Chart of the World
DFAD	Digital Feature Analysis Data
DIS	Data Interchange Services
DISA	Defense Information Systems Agency
DMA	Defense Mapping Agency
DOD	Department of Defense
DTED	Digital Terrain Elevation Data
EA	Evolutionary Acquisition
ED	Evolutionary Development
ELV	Elevation
FGDC	Federal Geographic Data Committee
FQT	Formal Qualification Test
GCCS	Global Command and Control System
GIS	Geographical Information System

GOTS	Government-Off-The-Shelf
IRRP	Rome Laboratory's Image Products Branch
ITD	Information Technology Division
ITD	Interim Terrain Data
JMTK	Joint Mapping Toolkit
JSWG	Joint Services Working Group
MACS	Mapping Application Client Server
MC&G	Mapping, Charting and Geodesy
MCG&I	Mapping, Charting, Geodesy, and Imagery
NDC	Normalized Device Coordinates
NITF	National Imagery Transmission Format
PDC	Physical Device Coordinates
R&D	Research and Development
RL	Rome Laboratory
RPF	Raster Product Format
SDB	Spatial Data Base
SDBM	Spatial Data Base Module
SDT	Spatial Display Tool
SOW	Statement of Work
SRS	Software Requirements Specification
TBMCS	Theater Battle Management Core System
TEM	Topographic Evaluation Module
U.S.	United States
USAF	United States Air Force
VMAP	Vector Smart Map
VPF	Vector Product Format
VSC	View Surface Coordinates
WWMCCS	World-Wide Military Command and Control System

APPENDIX C GLOSSARY

Application Programmer's Interface (API): A paradigm used to provide the interfaces between an application and a software library of functions, a toolkit of functions, or another application. The API can also refer to a collection of functions providing the interface capability to a software library, a toolkit of functions, or another application.

Cartographic Display Process: The method used to draw a cartographic map feature (e.g., VPF data features) in the CMTK cartographic window.

Common Mapping Toolkit (CMTK): A software library of functions which provide the capability to display, manipulate, perform geospatial analysis, and otherwise exploit Common Mapping Standard (CMS) data (preprocessed from DMA standard data) as well as other data sources for the United States Air Force.

Common Mapping Standard (CMS): A standardized, Government-owned and DMA-validated cartographic data base structure used as the CMTK data base. The data it incorporates is imported from existing DMA data products such as ADRG, ADRI, DCW, DFAD, DTED, etc. It provides a common format for the use of these varying DMA data products.

Compressed ARC Digitized Raster Graphic (CADRG): A general purpose product, comprising computer-readable digital map and chart images. It supports various weapons: Command, Control, Communications, and Intelligence (C3I) theater battle management; mission planning; and digital moving map systems. CADRG data is derived directly from ADRG and other digital sources through down sampling, filtering, compression, and reformatting to the RPF Standard. CADRG files may be physically formatted within a NITF message.

Controlled Image Base (CIB): A dataset of orthonormalized and rectified grayscale images. A CIB supports various weapons, C3I theater battle management, mission planning, and digital moving map systems. CIB data are derived and produced directly from digital images, and are compressed and reformatted to conform to the RPF Standard.

Dataset Metadata: A Level 3 metadata file within an SDBM Spatial Data Base. It describes a particular dataset found within a data base.

Data Base Metadata: The top level (Level 1) of metadata within an SDBM Spatial Data Base. It describes the contents of a particular data base.

Digital Chart of the World (DCW): A DMA product providing 1:1,000,000 scale vector geographic data. DCW was developed as the initial product implementation of a multinational R&D project designed to develop a set of vector product standards oriented toward the Geographical Information System (GIS) environment. DCW data was derived from Operational Navigational Charts over most of the globe and Jet Navigational Charts over Antarctica. The DCW product is the original name for the current VPF standard product, VMAP Level 0.

Digital Terrain Elevation Data (DTED): A DMA product providing a uniform matrix of terrain elevation values for the earth's surface at 100 meter resolution. The information content is approximately equivalent to a 1:250,000 scale resolution.

GCCS Common Operating Environment (COE): Defines a distributed application infrastructure that promotes interoperability in a reliable and scalable environment. Specifically,

a set of integrated services that support mission software application requirements, and a corresponding software development methodology and environment.

Geographic Reference System (GEOREF): A system used for position reporting. It is an area-designation method used for interservice and interallied position reporting for air defense and strategic operations. Positions are expressed in a form suitable for reporting and plotting on any map or chart graduated in latitude and longitude (with Greenwich as prime meridian) regardless of map projection. Referred to as GEOREF.

G-Odesy: An application which exercises a major portion of the CMTK API-level functions. It was developed during the CMIC effort and is used to provide developers with an environment conducive to modifying, testing, and exercising any portion of the CMTK source code quickly and easily.

Global Command and Control System (GCCS): Will become the single Command, Control, Communications, Computers, and Intelligence (C4I) system to support Joint warfighter. The system objectives are to replace the World-Wide Military Command and Control System (WWMCCS), and to implement the C4I for the Warrior concept. The result will be a single view of the military C4I that improves the Joint warfighter's ability to manage and execute operations.

Graphics Transformation: The conversion of points from one coordinate system to another using a transformation matrix. Graphics transformations include translation, scaling, and rotation.

Joint Mapping Toolkit (JMTK): A collection of application programmer interfaces (APIs) that enable support applications to interface with Mapping, Charting, Geodesy, and Imagery (MCG&I) functionality. This release of JMTK (version 3.0) is comprised of three distinct modules that interact with each other through the defined APIs. The Visual Module provides map presentation functionality. The Analysis Module performs geospatial computations. The Spatial Data Base Module provides the geospatial data management services.

National Imagery Transmission Format (NITF): A collection of related standards and specifications developed to provide a foundation for interoperability in the dissemination of imagery and imagery-related products among different computer systems, as defined in MIL-STD-2500.

Normalized Device Coordinates (NDC): A coordinate system used to address pixels on a computer graphics screen. The range of this coordinate system is similar to physical device coordinates, except that the largest dimension (width or height) is set to 1.0. The NDC position (0.0, 0.0) is in the lower left corner of the screen. If the width and height are equal, then the upper right corner of the screen is NDC position (1.0, 1.0). If NDC coordinates are used, then graphics objects will take up the same proportion of all computer screens, regardless of the actual PDC dimensions of the screen.

Physical Device Coordinates (PDC): A standard coordinate system used to address pixels on a computer graphics screen. The range of this coordinate system is dependent, but in a typical system the PDC of the upper left pixel will be (0, 0) and the PDC of the lower left pixel will be (width-1, height-1), where width is the number of pixels across the screen in the horizontal direction, and height is the number of pixels across the screen in the vertical direction. Some systems may have PDC (0, 0) in a different corner and PDC (width-1, height-1) in the diagonally opposite corner.

Pixel: A picture element. The smallest addressable area of a computer screen or image file.

Raster Product Format (RPF): A standard data structure for geospatial data bases composed of rectangular arrays of pixel values (e.g., digitized maps or images) in compressed or uncompressed form. RPF is intended to enable application software to use the data in the original format on computer-readable interchange media directly without further manipulations or transformations.

Rotation: A graphics transformation in which a coordinate system is rotated about its origin by a fixed angular value.

Scaling: A graphics transformation in which a coordinate system is resized into a larger or smaller coordinate system with possibly a different aspect ratio.

Spatial Data Base Module (SDBM): The module within the Joint Mapping Toolkit representing all activities dealing with data handling. Those areas include spatial data import, spatial data management, spatial data manipulation, spatial data base services, and spatial data export.

Spatial Display Tool (Sdt): An application developed to provide a single comprehensive, digital multisource MCG&I information handling capability.

Thread Tracker: A utility developed during the development of JMTK 3.0. It provides the capability to track the functional hierarchy, or functional threads, within a toolkit of functions during execution time. It can be turned off and on as needed.

Transformation Matrix: A 3x3 matrix to be multiplied by a point (stored as a vector) to produce a corresponding point (vector) in a different coordinate system. A 3x3 matrix will transform a two dimensional point. A transformation matrix can be as simple as an identity matrix, in which case the output is identical to the input, or any combination of translation, scaling, and rotation matrices.

Translation: A graphics transformation in which a coordinate system is moved vertically and/or horizontally.

Vector Product Format (VPF): The DMA's standard format for vector data. A general user-oriented data format for representing large spatially referenced data bases. VPF is designed to be used directly where software can access the data without time consuming conversion processing. VPF is also designed to be compatible with a wide variety of users, applications, and products.

Vector Smart Map (VMAP) Level 0: The low resolution component of DMA's VMAP family of products. Known as VMAP Level 0, it is a comprehensive 1:1,000,000-scale vector basemap of the world. It consists of geographic, attribute, and textual data stored on CD-ROMs. To show product lineage, it is dual named VMAP Level 0 as well as Digital Chart of the World (DCW). The name VMAP Level 0 will be the only name to continue beyond the initial release of the Vector Smart Map Level 0 data.

View Surface Coordinates (VSC): A coordinate system used to address pixels on a computer screen. The range of this coordinate system is the same as that of PDC, but on all systems the VSC of the lower left pixel will be (0, 0), and the VSC of the upper right pixel will be (width-1, height-1). VSC should be used in place of PDC wherever possible to allow for system portability.

Volume Metadata: A Level 2 metadata file within an SDBM Spatial Data Base. It describes the data types (i.e., DCW, CADRG, DTED) found within a data base and the datasets present for a data type.

***MISSION
OF
AFRL/INFORMATION DIRECTORATE (IF)***

The advancement and application of information systems science and technology for aerospace command and control and its transition to air, space, and ground systems to meet customer needs in the areas of Global Awareness, Dynamic Planning and Execution, and Global Information Exchange is the focus of this AFRL organization. The directorate's areas of investigation include a broad spectrum of information and fusion, communication, collaborative environment and modeling and simulation, defensive information warfare, and intelligent information systems technologies.